EFFECT OF SOME GASEOUS CONTAMINANTS IN THE ATMOSPHERE ON PHOTOSYNTHETIC ACTIVITY OF CHLORELLA

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The system of biological regeneration of air based on photosynthesis of /475
Chlorella is the simplest example of an ecological system with closed gas exchange. Its atmosphere is the element of the environment through which the principal interactions take place between man, algae, and certain nonliving components of the system.

The utilization of carbon dioxide excreted by man and regeneration of oxygen, i.e., the relationship between respiratory and photosynthetic gas exchange, is not the only relationship between man and the plants, because the many-sided biochemical activity of man and plants under the conditions of a single air environment introduces a number of new, and, in particular, toxicologic problems [1, 5].

The atmosphere of a closed living space is known to contain a number of gaseous contaminants, originating from man and plants and also from various materials of the cabin itself and of its furnishings. An essential element of the investigation during the development of systems of biological air regeneration must therefore be an experimental ecological analysis of the air environment as a single medium of habitation of man and plants where each component of the atmosphere may have definite ecological significance both for each living element of the system directly and also indirectly through other elements.

The functional unity of the system of mutual provision for the gas exchange needs of man and plants requires its study as a unified system. However, this does not rule out but, on the contrary, demands a preliminary isolated analysis of the special properties of each component from the point of view of their importance to other elements of the system.

For instance, the development of photosynthetic systems of air regeneration raised the problem of the suitability of the regenerated atmosphere for respiration, because we know that plants secrete a number of substances harmful to man into the atmosphere. The experimental investigation of this problem as applied to cultivators of unicellular algae (Chlorella) revealed the practical importance of such a study and the need for further research in this direction [2].

On the other hand, we know that man is a constant source of excretion into /476
the atmosphere of various volatile metabolic products. In particular, the dynamics of excretion of ammonia, aldehydes, carbon monoxide, ketones, hydrogen sulfide, mercaptans, hydrocarbons, fatty acids and other contaminants harmful to man and their accumulation in the inhabited atmosphere has been studied in some detail [1].

Meanwhile some of these substances possess physiological activity with respect to metabolic processes in plants, and thus influence their photosynthetic activity. The ready solubility of many of these volatile contaminants in water makes them inevitable components of the medium in which the algae live, thus calling for investigation of the actual influence of these substances on the physiological state and photosynthetic activity of algae in the air regeneration system.

In this paper we give preliminary results showing the effect of individual anthropogenic components of the inhabited atmosphere and of a group of contaminants present in human expired air on photosynthesis of Chlorella. We studied the action of ammonia, carbon monoxide, hydrogen sulfide and acetone, and also of air expired directly by man into the gas system of the gas exchanger. The investigations were carried out in a rotation type of gas-exchange apparatus with an air volume of 25 or 65 liters and an intensity of illumination of about 26 klux. The algae (Chlorella pyrenoidosa) were cultivated on Tamiya's medium in air containing from 2 to 5% CO_2.

The scheme of the experiment was as follows: over a period of 4-6 h the rate of photosynthesis was recorded under normal conditions of cultivation on the basis of the rate of absorption of CO_2 from the air circuit of the system. A gas analyzer of "Uras" type was used for this purpose, enabling continuous automatic recording of the CO_2 concentration in the air. After a constant rate of photosynthesis had been established (control experiment), the gaseous substance to be investigated was introduced into the air circuit of the system and the rate of photosynthesis was again recorded for several hours.

The effect of addition of the test substance was calculated as the positive or negative change in velocity of photosynthesis after addition of the substance as a percentage of the initial velocity obtained in the control experiment.

During the experiment the density of the suspension usually increased within the range 700-3000 million cells/ml, corresponding to the zone of linear increase in density of the culture when grown under these conditions and in this cultivator.

The concentration of substances under study, when measured 1 h after their introduction and at the end of the experiment, varied within the following limits in different experiments: carbon monoxide from 0.1 to 0.04, ammonia from 0.04 to 0.02, acetone from 0.06 to 0.01 and hydrogen sulfide under 0.0034 mg/ /477
liter.

By the end of the experiment the concentration of all these substances in the air had fallen.

To study the effect of small concentrations of carbon monoxide and acetone and of expired air on the photosynthetic activity of Chlorella, five experiments were carried out in each case; in addition, three further experiments were performed to study the action of small concentrations of hydrogen sulfide and ammonia. The results obtained are given in Tables 1-5.

TABLE 1. Change in Rate of Photosynthesis of Chlorella under Influence of Low Concentrations of Ammonia

Duration of experiment, h	Ammonia concentration in air, mg/liter		Change in density of suspension during experiment, millions of cells/ml	Change in rate of CO_2 absorption, % of control
	After 1 h	At end of experiment		
6	0,02	0,002	1845—2132	+4
18	0,02	0,002	689—1394	+9
17	0,03	Traces	720—1216	+14

Commas represent decimal points.

As Table 1 shows, in the last two experiments a slight stimulant effect was observed, due to absorption of a considerable part of the ammonia from the gaseous phase. There is no justification for regarding this effect as to any degree specific. Under the conditions of these experiments, ammonia has no direct action on Chlorella cells, because it is combined in the culture medium in the form of ammonium carbonate, used by algae as a source of nitrogen.

TABLE 2. Changes in Rate of Photosynthesis of Chlorella under Influence of Low Concentrations of Carbon Monoxide

Duration of experiment, h	CO concentration in air, mg/liter		Change in density of suspension during experiment, millions of cells/ml	Change in rate of CO_2 absorption, % of control
	After 1 h	At end of experiment		
12	0,107	0,02	826—1428	+17
5	0,036	0,015	2500—2950	+53
8	0,100	0,047	984—1806	+41
9	0,003	Traces	970—2226	+24
4	0,09	0,04	1611—1956	+19

Commas represent decimal points.

These results are of course insufficient to allow definite conclusions to be drawn, but to some extent they agree with the findings of V. V. Pinevich and

co-workers [3] indicating that Chlorella utilizes ammoniacal forms of nitrogen in preference to other sources of nitrogen feeding.

Data showing the effect of small doses of carbon monoxide are given in Table 2.

It is clear from Table 2 that after introduction of carbon monoxide into the gas exchanger the mean CO_2 utilization by the Chlorella cells increased in every case by between 17 and 53%. A similar effect was observed in experiments to study the action of acetone (Table 3).

TABLE 3. Changes in Rate of Photosynthesis of Chlorella under Influences of Small Concentrations of Acetone

Duration of experiment, h	Acetone concentration in air after 10 min, mg/liter	Change in density of suspension during experiment, millions of cells/ml	Change in rate of CO_2 absorption % of control
2	0,02	1050—1102	+24
3	0,005	2300—2417	+18
3	0,06	3100—3341	+11
2	0,016	800—890	+ 4
5	0,005	2300—2625	+16

Commas represent decimal points.

It follows from the results in Table 3 that the character of the changes in the rate of photosynthesis under the influence of acetone was similar to that observed during the action of carbon monoxide, but the intensity of the stimulant effect was significantly smaller in this case. The maximal increase in the rate of CO_2 absorption by the cells here was 24%. /478

The results of experiments to study the action of hydrogen sulfide are given in Table 4.

The results in Table 4 show that in two experiments with a higher concentration of hydrogen sulfide it had a marked inhibitory action, in full agreement with its blocking properties toward enzyme systems containing heavy metals [4].

Of the five experiments with expired air, three (Nos. 2, 3 and 5) gave some evidence of slight inhibition of photosynthesis (Table 5).

A noticeable feature in the experiments with expired air was that in none of them was a stimulant effect obtained, as was nearly always observed in our other investigations (G.I. Meleshko) in which the air medium for Chlorella was the air from an inhabited airtight cabin containing not only expired air, but also the whole range of gaseous contaminants excreted as a result of human metabolic activity. /479

The results of this investigation clearly do not yet justify final conclusions, and one of its purposes is to draw the attention of investigators to this problem.

TABLE 4. Changes in Rate of Photosynthesis of Chlorella under Influence of Small Concentrations of Hydrogen Sulfide

Duration of experiment, h	Hydrogen sulfide concentration in air, mg/liter	Changes in density of suspension during experiment, millions of cells/ml	Change in rate of CO_2 absorption, % of control
7	Less than 0,0001	1140—1785	—4
7	0,0034	1550—1894	—44
5	0,0025	1250—1897	—22

Commas represent decimal points.

TABLE 5. Changes in Rate of Photosynthesis of Chlorella under Influence of Human Expired Air

Duration of experiment, h	Change in density of suspension during experiment, millions of cells/ml	Change in rate of CO_2 absorption, % of control	Duration of experiment, h	Change in density of suspension during experiment, millions of cells/ml	Change in rate of CO_2 absorption, % of control
6	940—1228	—2	3	1700—1920	—6
4	900—1168	—12	11	1080—2052	—19
2	1300—1407	—20			

This work is merely a preliminary attempt to establish the phenomenologic aspect of the situation insofar as it concerns concentrations of certain gaseous contaminants actually found in the inhabited atmosphere. However, in the first stages of the investigations, even the purely phenomenologic approach can prove useful. In particular, for instance, subsequent confirmation of the results obtained in this investigation concerning the absorption of carbon monoxide, ammonia and acetone from regenerated air by Chlorella cells, with a distinctly positive effect on photosynthesis, would be grounds for reexamining the question /480 of the need for special filters to absorb these substances when present in photosynthetic systems.

We consider that the study of the problems discussed in this paper must in the future form a permanent component of experimental ecological investigations of animal-plant associations.

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